Individual event probabilities

For 203 data set N_{bkg} = .35 ie. It's calculated that ~.35 background events will pass our tau selection cuts

Results of ν_τ selection can be sated in two ways:

1. A signal of 4 events with an expected background of .35 events

   The Poisson probability of all signal events being background

$$f(N:m) = \frac{m^N \cdot e^{-m}}{N!} = \frac{.35^4 \cdot e^{-.35}}{4!} = 4.4 \times 10^{-4}$$

2. Using individual analysis, probabilities for each individual selected event are given

   The probability that event is a ν_τ and is not one of the background processes which make up N_{bkg} can be quantified : P(event|ν_τ)

   Since all events are independent, the probability that all events are background is

$$P_{all\_bkg} = \prod_i (1 - P(i\,|\,n_t) = 7 \times 10^{-5}$$

- Probability analysis can be used as selection criteria → clean signal

Individual event probabilities: Bayesean

$$P(hypothesis_\alpha \mid \vec{e}) = \frac{A_\alpha \cdot PDF(\vec{e} \mid hypothesis_\alpha)}{\sum A_i \cdot PDF(\vec{e} \mid hypothesis_i)}$$

P = The probability of an event *e* being a result of hypothesis α.

α = *tau*, *interaction* *or* *charm* event

Two inputs for each hypothesis:

1. A_i prior probability:

   Previous knowledge of the likelihood of each hypothesis

   "Relative Normalization"

2. PDF (hypothesis$_\alpha$| x) probability density at x under hypothesis

   Definition: PDF(x) Δx = Probability of finding x in (x, $x+\Delta x$)

   "Distribution of parameters which define event"

1-D example: ν_τ vs interaction

Assume the only possibilities are ν_τ or hadron interaction.

Use only one parameter Φ to evaluate event.

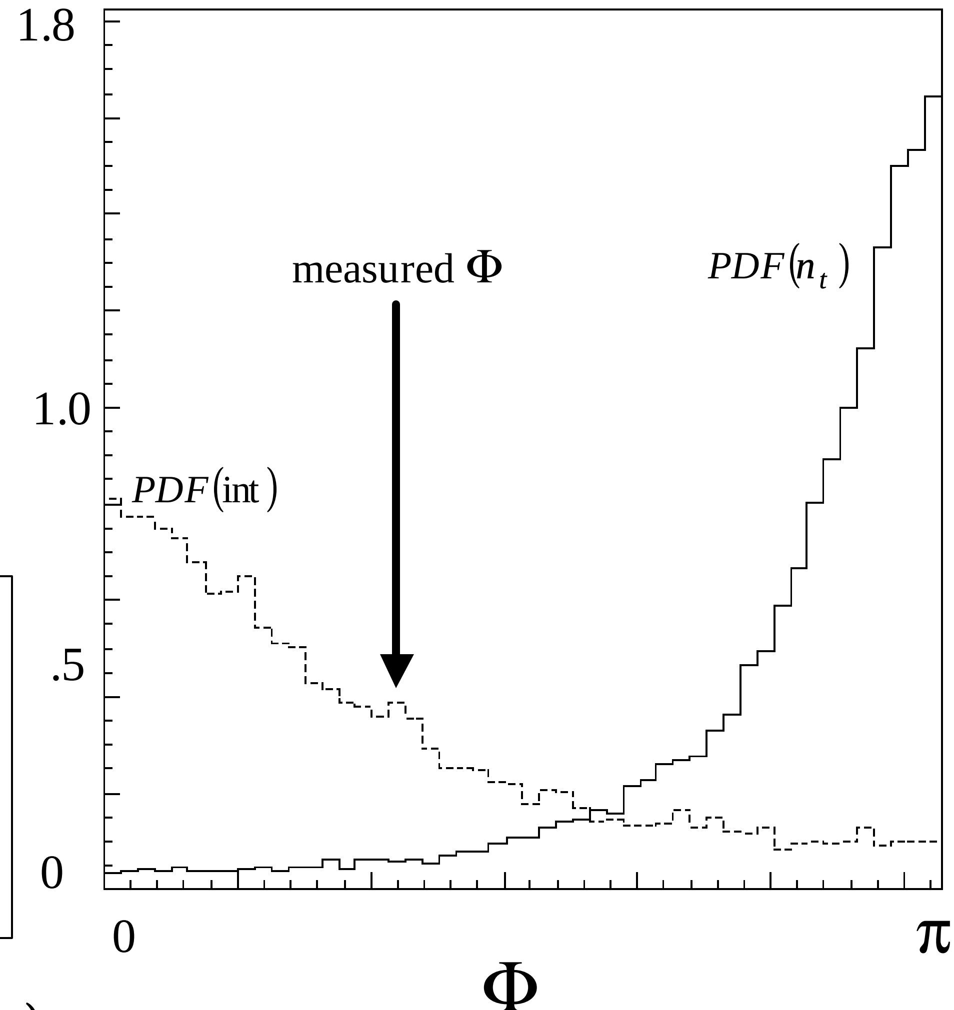
3024_30175 has $\Phi = 1.04$

$$P(n_t \mid \Phi) \equiv \frac{A_n \cdot PDF(\Phi \mid n_t)}{A_n \cdot PDF(\Phi \mid n_t) + A_{\text{int}} \cdot PDF(\Phi \mid n_t)}$$

Expect .16	interaction evts.	A_{int}	.16
Expect 4.2	ν_τ events	$A_{\nu\tau}$	4.2

PDF(int. | Φ = 1.04) = .38

PDF(ν_τ | Φ = 1.04) = .06



$$P(n_t \mid \Phi = 1.1) = \frac{(4.2)\cdot(.06)}{(4.2)\cdot(.06) + (.16)\cdot(.38)} = .78$$

Prior Probabilities

- Prior probability of a hypothesis is proportional to the total number of this event type expected to pass the selection cuts. ie. N_{tau} , N_{charm} or $N_{interaction}$

Focus of this presentation is on

1. Expected number of ν_τ interactions
2. Expected number interactions

- N_{tau} expected has large uncertainty due to uncertain values of :

  total $\sigma(D_s)$: 30%

  parameterization of D_s production : uncertainty in differential cross-section results in uncertainty in interaction rate of ~ 20%

  efficiency of selection, location of tau events

- $N_{interaction}$ background has uncertainty due to:

  λ_{steel}, $\lambda_{emulsio}$ and $\lambda_{plastic}$ for kink type hadron interactions

N_{tau} from ratio of rates ν_τ/ν_e or ν_τ/ν_μ from charm

$$N_{tau} = N_{n_m} \cdot \frac{Rate_{n_t}}{Rate_{n_m}} \cdot \frac{E_{n_t}}{E_{n_t}} \qquad N_{tau} = N_{n_e} \cdot \frac{Rate_{n_t}}{Rate_{n_e}} \cdot \frac{E_{n_t}}{E_{n_t}}$$

To reduce or eliminate uncertainties contributing to Ntau we can express expectation in terms of numu or nuee from similar sources (prompt)

+ Uncertainty in relative rate and relative efficiency are much smaller
+ Uses measured values of ν_μ or ν_e : less reliance on Monte Carlo

– Uses measured values of ν_μ or ν_e : uncertainty of measured number

Ratio of interaction rates

$$R_{n_t} = \frac{s\,(D^0)}{s\,(pW)} \cdot \left\langle \frac{s\,(D_s)}{s\,(D^0)} \right\rangle \cdot Br(D_s \rightarrow n_t) \cdot 2 \cdot \int h(E)\, s\,(E)\, \frac{dN}{dE} dE$$

$$R_{n_a} = \sum_i \frac{s\,(pW \rightarrow Charm_i)}{s\,(pW)} \cdot Br(Charm \rightarrow n_a) \cdot \int h(E)\, s\,(E)\, \frac{dN}{dE} dE_a$$

η(E) is target acceptance fraction,   σ(E) is neutrino cross-section

dN/dE is spectrum: neutrino energy depends on charm production distribution

$$\frac{d^2 s}{dx_f\, dpt^2} \propto (1 - xf)^n \cdot e^{-bpt^2}$$

$$\frac{R_{n_t}}{R_{n_a}} = \frac{\left\langle \frac{s\,(D_s)}{s\,(D^0)} \right\rangle \cdot Br(D_s \rightarrow nt) \cdot \int h(E)\, s\,(E)\, \frac{dN}{dE}}{\sum_i \left\langle \frac{s\,(C_i)}{s\,(D^0)} \right\rangle \cdot Br(C_i \rightarrow n_a) \cdot \int h(E)\, s\,(E)\, \frac{dN}{dE} dE_a}$$

Cross-section ratio

Experiment		D_s/D^0	D^+/D^0
CLEO	e+e-	.32±.14	.38±.10
NA32	Pion	.24±.10	.51±.15
WA92	Pion	.16±.05	.42±.05
E653	Pion	-	.4±.1
E653	Proton	-	.8±.4
E691	Gamma	.14±.04	.51±.11
E769	Pion+	.28±.07	.44±.06
E769	Proton	.27±.18	.42±.05
E769	Pion-	-	.27±.06
E791	Proton	-	.57±.22
Mean		.18±.03	.41±.02

Charm production parameters

Experiment	b	n
E653	.84±.09	6.9 ±1.9
E743	.80±.2	8.6±2.0
Mean	.83 ±.11	7.7 ±.1.4

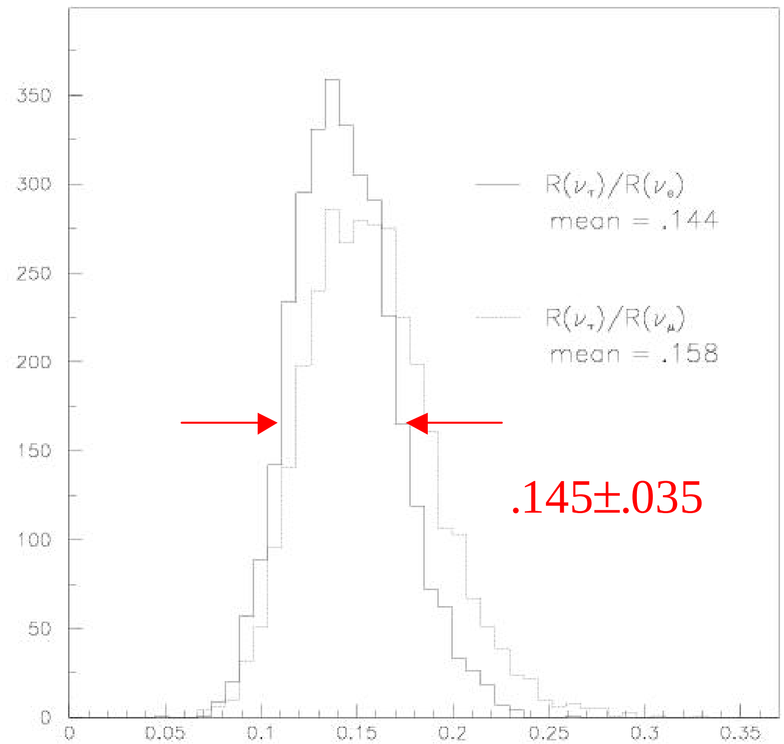
D_s branching fraction

$D_s \quad \nu_\tau$	BR %
CLEO	6.6 ± 1.1
WA 75	5.6 ± 1.7
BES	9.7 ± 3.8
E653	6.6 ± 1.0
L3	7.1 ± 1.9
DELPHI	7.6 ± 1.1
Mean	6.6 ± 0.6

Charm branching fractions (PDG)

Decay	BR %
$D^+ \quad \nu_e$	17.2 ± 1.9
$D^0 \quad \nu_e$	6.75 ± .29
$D_s \quad \nu_e$	8 ± 5
$D^+ \quad \nu_\mu$	16 ± 3
$D^0 \quad \nu_\mu$	6.6 ± 0.8
$D_s \quad \nu_\mu$	8 ± 5

Interaction rate ratio



<u>One MC trial</u>

1. Produce charm using selected ratios
2. Simulate neutrino production through charm decay
3. Find fraction of produced neutrinos passing through detector weighted by interaction cross-section.
4. Repeat 2-4 until 10,000 ν_τ produced

•10,000 trials with 10,000 ν_τ each

•Varying all inputs by uncertainty

•Interaction probability weighted by cross-section of generated neutrino

Interaction background

Calculate # by material : $N_{interaction} = N_{Fe} + N_{base} + N_{emul}$

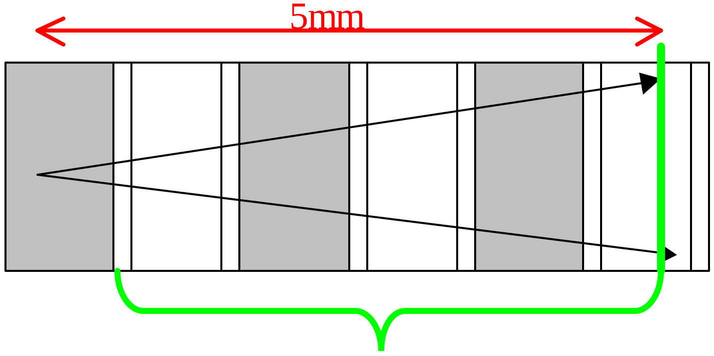
$N_{int} = L\,\lambda\,P_{ll}$

λ mean free path for single charge interaction (kink type) which pass tau selection cuts : pt > 250 MeV & momentum> 1 GeV

P_{ll} probability of no lepton being found = $F_{NC} + F_{\mu CC}*(1-\varepsilon_{\mu}) + F_{eCC}*(1-\varepsilon_{e})$

calculated from Monte Carlo

L total path length of all primary particles: from data



L : Only from first segment to a total of 5mm from vertex

Path length in cm.

	ECC events	BULK events
Emulsion	28.0	105.5
Plastic	74.7	14.1
Fe	131.7	-

(203 data set)

Mean free path of interaction : CHARON experiment

CHARON measured pion interaction in emulsion stacks: 2, 3, and 5 GeV pions

pt > 250 MeV/c

λ of white star kinks WSK

λ of gray star kinks GSK (low activity interaction $\rightarrow$ ECC background)

Results for emulsion can be *scaled* for Fe and plastic:

composite material has mean free path $$l_j^{-1} = N_A \cdot \sum_i w_i \cdot s_i \cdot A_i^{-1}$$

cross-section has nuclear dependence of $\sigma \propto A^{\alpha}$, $\alpha = .71$

$$\frac{MFP_J}{MFP_{Emul}} = \frac{r_{Emul} \cdot \sum_i^{Emul} w_i \cdot A_i^{1-a}}{r_J \cdot \sum_i^{J} w_i \cdot A_i^{1-a}}$$

	2GeV/c	3GeV/c	5GeV/c	E872
WSK bulk	**134 ± 90**	**47 ± 16**	**49± 18**	**60 ± 25**
GSK bulk	**14 ± 4**	**27 ±9**	**23 ± 13**	**20 ± 9**
WSK scaled to Fe				**29 ± 13**
GSK scaled to Fe				**9.6 ± 4.3**
WSK scaled to lucite				**117 ± 54**
GSK scaled to lucite				**39 ± 18**

Mean free path of interaction : MC

1. Primary hadrons from a LEPTO simulation of neutrino interactions are propagated through an EC800 emulsion stack to simulate emulsion record.

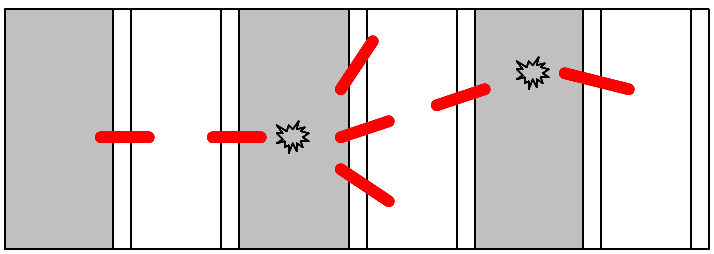
   Momentum is smeared by $\Delta p/p = 30\%$

   Track segment recorded if particle traverses entire 100μ of emulsion

2. Kinks satisfying the tau selection cuts are chosen.

   only "kink type" interactions & pt , momentum, max. angle cuts

3. $\lambda =$ number of kinks seen/ total path length simulated



Kink is counted *iff* 1 segment is visible in downstream side.

	Steel	Lucite
$\int$Path length	11.3 km	11.5 km
# kinks	1473	463
λ	7.7 m	24.8 m
λ_{total} CHARON (wsk +gsk)	7.2 m	30 m

Interaction background results

$$N_{int} = L\,\lambda^{-1}\,P_{ll}$$

$P_{ll} = F_{NC} + F_{\mu CC} * (1-\varepsilon_\mu) + F_{eCC} * (1-\varepsilon_e)$ from Monte Carlo ~.48

BULK CHARON result for WSK only: $\lambda = 60 \pm 25$ m

ECC $\lambda_{plastic}$ for ECC 800 is lower limit for ECC200: low energy fragments which identify GSK are more likely to be recorded in emulsion in ECC200 $\lambda_{plastic}$ MC = 24.8m

λ_{Fe} is identical for ECC800 and ECC200

λ_{Fe} MC = 7.7 m

N_{bulk}	= (1.33m) (1/60m)(.48)	= .010
$N_{plastic}$	= (.747m) (1/24.8m)(.48)	= .014
N_{steel}	= (1.32m) (1/7.7)(.48)	= .082
	$N_{interaction}$	= .106